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SCIENTIFIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 372

WAVE LENGTHS LONGER THAN 5500 A IN THE ARC SPECTRA OF SEVEN ELEMENTS

BY

C. C. KIESS, Associate Physicist, and
W. F. MEGGERS, Associate Physicist
Bureau of Standards

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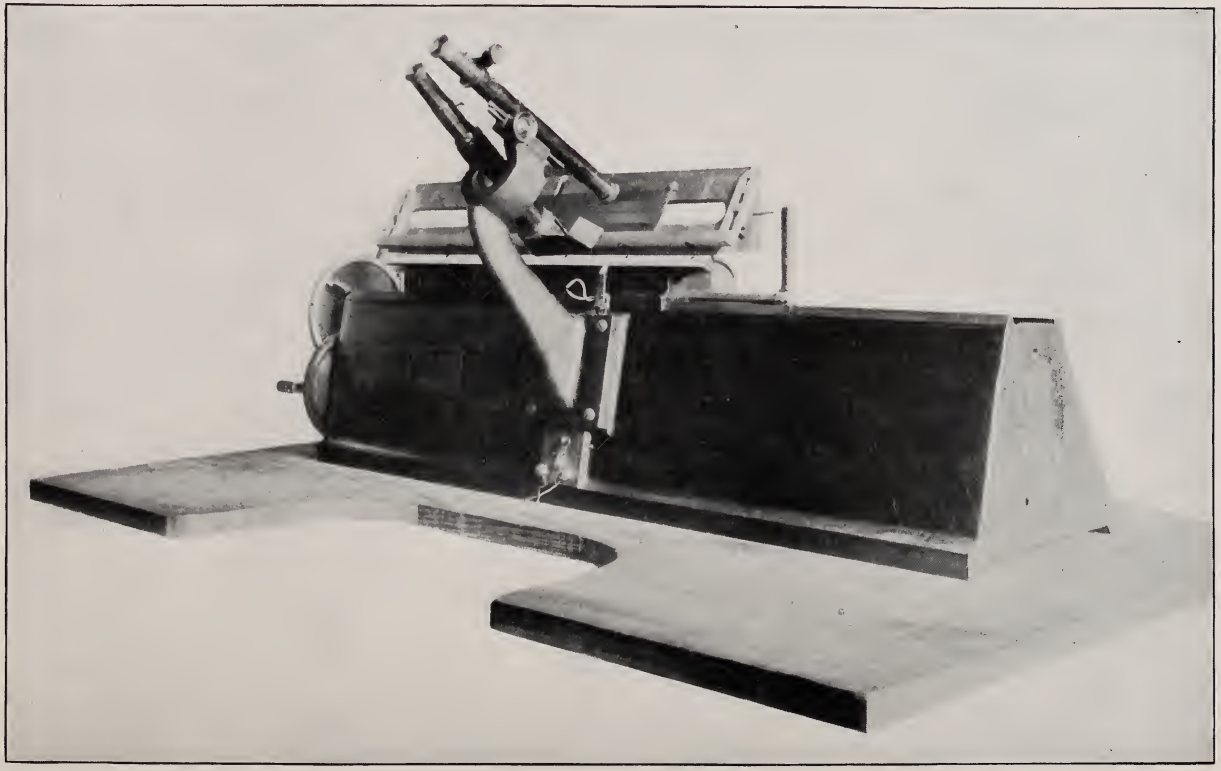

FIG. 1.—*Measuring engine*

WAVE LENGTHS LONGER THAN 5500 A IN THE ARC SPECTRA OF SEVEN ELEMENTS

By C. C. Kiess and W. F. Meggers

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I. INTRODUCTION

The wave lengths in the arc spectra of titanium, vanadium, chromium, manganese, molybdenum, tungsten, and uranium presented in this paper form a continuation of the program of standard wave-length determination and spectroscopic analysis inaugurated at the Bureau of Standards several years ago. This program has as one of its objects the mapping of the red and infra-red spectra of the chemical elements as far out into the region of longer wave lengths as modern photographic methods will permit. The values given below are submitted, therefore, not only as a description of the red and infra-red regions of the various spectra, but also to serve as starting values for the more precise determinations of interferometry. Similar results for 15 other elements have thus far been published.[1] Work on others is in various stages of progress, and it is hoped that this phase of the program may be completed within a few years.

II. APPARATUS AND METHODS

In the present work no essential departure was made from the methods of observing described in the papers referred to above. All the plates were exposed in the first order of the concave grating with the exception of two, for which the second order was used in photographing the region from 6500–7500 A

[1] B. S. Bulletin, 14, p. 371, 1918; 14, p. 637, 1918; 14, p. 771, 1918.

for chromium, tungsten, and molybdenum. The plates were measured on a large engine constructed by Gærtner, which is illustrated in Fig. 1. Its smallest scale division is 0.001 mm, which corresponds to 0.010 A in photographs of the first-order spectrum.

For tungsten and molybdenum, rods served as electrodes; for the other elements, small pieces of the metal placed in the cored ends of copper rods were used. We have found this latter procedure preferable to the use of graphite electrodes, partly because of the steadiness with which the arc burns when a copper bead from the upper electrode is fused with the metal in the lower electrode and partly because of the relatively small number of copper lines that occur in the longer wave-length regions. Some of these copper lines may in rare instances be inseparable from lines of nearly the same wave length occurring in the spectra of other elements. With the exception of uranium, for which the nitrate was used, all the elements were burned in their uncombined form.

The photographs were made on Seed 27 and Seed 30 plates sensitized to the yellow and red regions of the spectrum with pinacyanol, dicyanin, and dicyanin A. The methods of using these dyes have been frequently described. In the course of other work carried on by the spectroscopic laboratory of the Bureau of Standards it became part of the routine work to test photographic dyes made by various laboratories to replace the German product, which was cut off by the war. Many of the plates used in the present study were sensitized with these new dyes, and it is a pleasure to testify that the pinacyanols produced in the United States are equal to their predecessors in every respect.

The arc spectrum of iron served as a comparison spectrum, and its wave lengths determined by interference methods [2] were used in the reductions. The duration of exposures increased from about five minutes for the short waves to about five hours for the longest. In the case of long exposures, to eliminate temperature shifts the plate was exposed to the iron spectrum both before and after. Since, however, the room containing the spectrograph remains at practically constant temperature for long intervals of time, it is felt that the wave lengths presented below are free from error of this kind.

[2] B. S. Bulletin, 13, p. 245; 1916.

III. RESULTS

Each wave length given in the following tables is, in general, the mean of from two to eight determinations. Each plate in the first order covers 2000 angstrom units, and three or more photographs were made of spectral regions which overlap each other by half this interval. Lines observed only once or twice were recorded by longer exposure than the average for a particular region.

Following each wave length are notes giving the intensity and character of the line. The intensities range from 1 for the faintest lines measurable to 10 for the strongest.

The letters have the following significance:

b=broad.
d=double.
g=ghost.
h=hazy.
l=shaded to red.
n=band head.
p=part of band structure.
R=reversed.
v=shaded to violet.

The last column of the tables indicates the probable errors of the measurement of each wave length, the letters having the significance:

A=probable error of 0.000 A to 0.010 A.
B=probable error of 0.010 A to 0.020 A.
C=probable error of 0.020 A to 0.030 A.
D=probable error $>$ 0.030 A.
E=only one determination.

Lines with probable errors A and B were measured three times or more.

It is hoped that these tables are free from the wave lengths of impurities, but although all the chemicals which were burned in the arc were the purest obtainable, yet it was found that none were spectroscopically pure. A number of faint lines were found to be common to the spectra of two or more elements. These are caused, no doubt, by some common impurities which, as yet, have not been identified. All such lines are given in Table 8, following the tables containing the wave lengths of the elements.

During the work on the spectrum of chromium it was found that a number of the infra-red lines were repetitions of the three strong lines at wave lengths 7355, 7400, and 7462 A. These

spurious lines are of the type first discovered by Lyman,[3] although the factors relating the false to the parent lines are not the same as those given by him. In all, seven factors giving false lines of apparent wave length greater than the parent line have been detected. These factors have been used to eliminate all false lines from the present tables. Unfortunately, our tables for iron, cobalt, and nickel, which were published at a time when it seemed that war activities would preclude further spectroscopic work in this laboratory for an indefinite period, contain many of these false lines.

The seriousness of this weakness inherent in work done with grating spectrographs is apparent and suggests that all gratings should be investigated for their "instrumental constants." To determine more exactly the nature of the false spectra produced by gratings, and particularly their relation to the method of ruling, a number of concave gratings have been borrowed and are now being studied. The results will be presented in a later paper.

1. TITANIUM

Approximately 200 wave lengths in the arc spectrum of titanium have been measured between the limits 5500 A and 9800 A. About one-tenth of the wave lengths presented are band heads, the bands, no doubt, having their origin in the oxide of titanium. Hundreds of lines belonging to bands were not resolved and were therefore not measured. The presence of bands and the relatively small number of strong lines in the red render the arc spectrum of this metal undesirable as a reference spectrum for the red regions. Kilby[4] has measured the wave lengths of the spectrum in international units, but his measurements extend only to 6261 A.

Among the wave lengths presented below (Table 1) are several pairs with constant frequency differences. Two of these pairs are of the type found by Paulson.[5] The data are as follows:

λ		ν	Δν	
5762.25	2 h	17 354.33	35.38	
5774.02	2 h	17 318.95		
5953.18	3	16 797.74	35.56	71.31
5965.81	3	16 762.18	35.75	
5978.56	3	16 726.43		
7978.87	4	12 533.10	71.78	
8024.83	2	12 461.32		

[3] Phys. Rev., **12**, p. 1, 1901; **16**, p. 257, 1903.
[4] Astrophysical Journal, **30**, p. 247; 1909.
[5] Paulson, Dissertation, Lund; 1914.

TABLE 1.—Arc Spectrum of Titanium

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5503.88	2	B	6295.32	1	E	7978.87	4	A
5512.49	4	C	6303.76	2	A	7996.49	3	A
5514.46	5, d	C	6305.65	1	E	8003.55	1	E
5565.48	2	B	6312.23	1	B	8024.83	2	A
5597.92	2, n	C	6316.42	1	E	8034.99	1	E
5629.39	2, n?	B	6336.10	1	B	8064.09	2, p?	E
5644.21	3	C	6366.38	2, Ni?	B	8068.21	2	B
5648.63	2	B	6446.27	2	B	8069.73	1	E
5662.12	2, d?	B	6454.22	2	B	8127.91	1	E
5675.48	2	A	6456.06	2, O?	B	8131.40	1	E
5679.97	1	B	6464.02	1	E	8180.45	1, n?	E
5689.51	2	A	6465.56	2	E	8207.32	1, n?	E
5702.67	1	B	6475.18	1	E	8241.49	1	E
5708.27	1	A	6497.71	1	E	8267.62	1	E
5713.93	1	B	6508.15	1	E	8289.07	1, n?	E
5716.48	1	A	6546.26	4	B	8306.27	2, h	E
5720.52	1	B	6554.22	3, l	B	8307.41	1	E
5739.46	2	A	6556.09	3	B	8311.71	2	E
5739.96	1	B	6575.19	1	E	8312.89	2, Co?	E
5741.28	1	B	6599.13	3	A	8334.42	2	E
5752.89	1, Co?	B	6651.27	1, n	E	8348.82	1, h	E
5762.25	2, h	B	6666.60	2, n, v	C	8353.12	2	E
5766.33	2, h	B	6681.13	1, n	E	8364.18	2	A
5774.02	2, h	B	6743.15	2	A	8377.83	2	A
5785.86	2, h, Cr?	B	6861.47	2	C	8382.61	3	A
5804.45	3, h	B	6996.69	1	B	8396.85	2	A
5823.74	1	B	7008.32	1	C	8412.34	3	A
5863.10	1, n	E	7010.94	1	B	8424.44	1	B
5866.45	4	B	7035.85	2	A	8426.46	4	A
5880.30	1	B	7038.83	3	B	8434.89	4	A
5888.70	1	E	7050.68	1	B	8435.64	5	B
5899.33	3	B	7054.38	4, n	A	8438.90	3	B
5903.33	1	C	7069.11	2, p?	A	8442.99	1	E
5918.54	2	A	7077.28	1	E	8450.89	3	B
5922.12	2	A	7077.88	1	E	8457.03	2, h	E
5937.79	1	B	7087.73	3, n	A	8467.13	2	B
5941.73	2	A	7125.62	3, n	A	8468.45	3	B
5953.18	3	B	7135.54	1, Ti?	C	8495.94	1	B
5965.81	3	A	7138.92	1, Ti?	B	8518.20	4	B
5978.56	3	A	7189.92	2, p?	A	8539.30	1	B
5999.66	2	A	7209.44	5	A	8548.06	2	B
6064.64	2	B	7216.19	3	A	8641.55	1	E
6070.98	1	E	7244.82	4	A	8675.33	2	B
6081.31	1	C	7251.74	4	A	8682.93	2	B
6085.24	3	B	7253.76	1, p?	E	8692.29	1	B
6091.20	3	B	7299.67	2	E	8734.69	1, h, Ti?	B
6092.79	1	B	7308.18	1	D	8859.70	1	E
6098.70	2	B	7318.43	2	A	8989.40	2	C
6121.03	1	C	7330.97	1, p?	E	9027.28	1	B
6126.22	3	B	7332.26	1, p?	E	9090.68	1	B
6138.38	1	E	7344.69	3	A	9123.09	1	B
6146.22	2	B	7352.14	1	E	9167.55	1	B
6148.80	1, n	D	7357.73	3	A	9246.18	1	C
6149.81	2, h	E	7364.11	2	B	9257.62	1	C
6159.02	2, n	B	7366.58	1	E	9285.02	1	C
6174.47	2, n	B	7440.58	3	A	9546.06	1	C
6186.34	2, n	B	7474.93	1, p?	E	9599.44	1	C
6215.23	3, h	B	7489.61	2	A	9638.26	2, h	B
6220.45	2, n	C	7496.12	2	A	9647.55	1, h	C
6221.42	2, p	B	7614.49	1, p?	E			
						9675.57	1	B
6222.56	2, p	E	7654.46	2	B	9705.63	1	C
6258.09	5	B	7926.34	1	B	9728.33	1	C
6258.73	5	B	7943.91	1, h, n?	B	9743.58	1, h	C
6261.08	4	B	7949.11	3	A			
6275.74	1, h	E	7961.59	2	A			

Some of Paulson's constant frequency differences have not been confirmed by recent wave-length measurements,[6] which are more accurate than those of Exner and Haschek, used by Paulson. Similar frequency differences of possibly related lines which are presented here may also be shown to be not strictly constant when more precise measurements are made. The frequencies, or numbers of waves per centimeter, are given for wave lengths as measured in air.

2. VANADIUM

Table 2 contains about 250 lines in the arc spectrum of vanadium between the limiting wave lengths 5500 A and 9522 A. Some of these lines belong to bands, but most of the band structures were not resolved, and therefore not measured. Shaw's[7] measurements extend from 5800 A to 7364 A, but only those wave lengths in his list shorter than 6500 A are given in international units. Vanadium has numerous sharp lines of intensity 2, or greater, in the region from 5500 A to 6600 A. However, the presence of bands in this region detracts from the desirability of using this portion of the vanadium spectrum as a comparison spectrum for standards.

New pairs of lines with constant frequency differences of the types found by Paulson[8] are as follows:

λ		ν	$\Delta\nu$
5507.75	3	18 156.23	28.66
5547.06	3	18 027.57	
5707.02	10	17 522.28	28.42
5716.29	4	17 493.86	28.53
5725.63	4	17 465.33	
5727.68	5	17 459.07	28.54
5737.06	6	17 430.53	
5776.65	3	17 311.07	28.57
5786.20	4	17 282.50	
6240.20	2	16 025.10	29.89
6251.87	5	15 995.21	
6243.06	9	16 017.79	29.84
6254.71	2	15 987.95	
6753.03	4	14 808.17	29.55
6766.53	3	14 778.62	
6256.91	3	15 982.33	30.44
6268.85	4	15 951.89	
6326.88	5	15 805.58	30.50
6339.11	3	15 775.09	

[6] Zeit. für Wiss. Phot., 17, pp. 79–142; 1917.
[7] Astrophysical Journal, 30, p. 127; 1909
[8] Paulson, Dissertation, Lund; 1914.

TABLE 2.—Arc Spectrum of Vanadium

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5504.84	1	E	6039.76	6	A	6543.53	2	A
5507.75	3	B	6048.69	1	A	6550.13	1	A
5511.11	1	E	6054.47	1	A	6558.05	2, V ?	A
5547.06	3	B	6058.15	4	A	6565.88	2	A
5561.75	2	B	6063.45	1	A	6568.81	1	A
5584.55	5	B	6067.25	2	B	6579.00	1	B
5592.48	5	B	6081.46	6	A	6605.98	3	A
5601.48	1	B	6086.67	1, n	C	6607.83	2	A
5604.94	6	B	6087.67	1	E	6623.59	1	B
5622.11	1	E	6090.25	7	B	6624.87	3	A
5624.69	8	B	6104.65	1	E	6633.35	1	B
5626.06	3	B	6106.97	1	A	6693.65	1	B
5627.67	8	A	6111.68	6	A	6708.03	1	B
5632.43	1	E	6119.56	6	A	6753.03	4	A
5635.56	1	E	6135.37	5	A	6760.12	2	A
5646.13	5	A	6150.18	5	B	6766.53	3	A
5657.45	7	B	6170.39	3	B	6785.02	2	A
5668.38	5	B	6189.37	2	B	6786.36	1	B
5670.88	7	A	6199.21	4	B	6812.42	2	A
5683.32	3	B	6213.90	2	B	6832.47	2	A
5687.83	2	B	6216.38	5	A	6839.59	2	A
5691.29	2	C	6218.36	2	A	6841.90	2	A
5698.52	9	A	6224.53	3	A	6870.86	2	A
5703.60	10	B	6230.80	7	A	6871.55	2	B
5707.02	10	B	6233.20	4	A	6894.00	1, n	B
5708.94	1	A	6240.20	2	A	6974.56	1	A
5716.29	4	B	6243.06	9	A	7026.06	1	B
5725.63	4	B	6245.26	2	B	7264.24	2	B
5727.02	7	B	6251.87	5	A	7321.47	1	B
5727.68	5	B	6254.71	2	E	7338.93	3	A
5731.28	6	A	6256.91	3	A	7345.11	2, n	B
5733.24	1	B	6258.58	3	A	7356.50	2	A
5734.01	3	A	6261.25	3	A	7358.62	1	A
5737.06	6	A	6266.32	3	A	7361.39	2	A
5743.45	5	B	6268.85	4	A	7362.55	1	B
5747.73	1	A	6274.68	5	A	7363.17	2	B
5748.84	2	B	6282.34	1	A	7393.39	2, n	E
5750.67	1	B	6285.18	4	B	7431.50	2, p	E
5755.15	1	C	6286.91	1	E	7434.00	2, p	E
5761.40	1	B	6292.85	5	A	7435.74	2, n	E
5772.44	3	A	6295.20	1	E	7578.78	1	B
5776.65	3	B	6296.53	5	A	7790.57	2, h	C
5782.71	1	B	6304.38	1	C	7801.78	1	C
5783.52	1	B	6311.53	2, b	A	7851.16	2	C
5784.45	3	B	6321.26	1	B	7865.51	2, n	C
5786.20	4	B	6324.69	1	B	7898.81	1	E
5788.52	3	A	6326.88	5	B	8027.34	2	B
5799.88	1	A	6339.11	3	B	8093.47	2	B
5807.16	1	B	6349.50	3	A	8102.37	2	E
5817.14	1	B	6355.66	2	A	8108.72	2	C
5817.61	2	B	6357.31	3	A	8109.01	2	C
5830.75	4	B	6358.80	3	A	8109.84	1	E
5846.35	6	B	6361.26	2	B	8116.78	5	A
5850.35	1	B	6379.35	2	A	8144.52	3	B
5924.59	3	B	6393.30	2	A	8154.52	2	A
5975.42	1	C	6430.49	1	A	8161.06	4	A
5978.94	2	B	6431.68	1	A	8171.30	3	A
5980.81	1	B	6433.15	2	B	8186.71	3	B
5984.74	1	C	6435.19	2	B	8187.38	3	B
6002.51	3, Co? d?	B	6445.21	1	C	8198.85	3	B
6008.69	1	E	6452.38	4	B	8203.11	4	B
6016.13	2	B	6477.55	1, n	E	8241.60	4	A
6017.95	2	A	6488.12	2	E	8253.48	4	A
6024.22	1	E	6504.18	4	A	8255.90	4	A
6025.43	2	A	6531.43	5	A	8280.37	1	A

TABLE 2—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
8282.36	3	A	8624.90	2,1	C	9226.10	1,h	E
8324.31	2	B	8657.83	1	E	9242.96	1	E
8331.23	2	B	8762.37	1,n	E	9255.91	1	E
8342.06	2	B	8919.78	3	B	9264.47	1	E
8402.78	2	B	8932.93	2	A	9265.69	1	E
8408.24	1,h	C	8971.65	1	A	9273.37	1	E
8414.42	1	B	9003.02	1	E	9308.80	1	E
8416.50	1	B	9021.10	2	B	9328.27	1	E
8421.37	1	B	9022.72	2	B	9341.06	1	C
8431.62	1	B	9037.55	2	B			
						9366.92	1	E
8468.17	1,p	E	9046.69	2	B	9385.15	1	E
8493.62	1	B	9073.34	1	E	9435.58	1	E
8499.51	2	B	9085.23	2,h	B	9521.87	1,h	E
8502.94	1	C	9100.74	1,b	B			
8505.55	2,v	B	9105.68	1	D			
8534.52	2	B	9113.76	1	E			
8538.19	1,n	E	9141.25	1	E			
8580.53	1,p?	E	9156.48	1	D			
8590.97	1,b	E	9164.80	1	B			
8604.98	1,b	E	9168.83	1	C			

3. CHROMIUM

The red and infra-red spectrum of chromium is characterized by the presence of several complex triplets of strong lines and a number of bands, presumably due to the oxide. In Table 3 are given 130 wave lengths between the limits 5564 A and 9735 A. Stüting's[9] work, based on the standard iron lines of Fabry and Buisson, extends from 5902 A to 7463 A. Meissner's[10] measurements refer only to the triplets in the red and infra-red regions, and the values given for them in the following table are in close agreement with his. Observing with a bolometer, Randall and Barker[11] have found many infra-red lines in the spectrum of chromium, beginning at wave length 8947 A. All of their lines up to 9732 A are to be found in Table 3.

The frequency differences of two sets of triplets in the red region of the spectrum have been calculated, and it is found that they are enantiomorphs of two other sets of shorter wave lengths. The data are as follows:

λ		ν	Δν	λ		ν	Δν
4254.34	12	23 505.41	112.50	7355.93	10	13 594.47	81.36
4274.80	12	23 392.91	81.37	7400.22	10	13 513.11	112.49
4289.72	10	23 311.54		7462.34	10	13 400.62	
5204.51	12, R	19 214.10	5.68	9009.95	6	11 098.84	8.80
5206.05	12, R	19 208.42	8.74	9017.10	5	11 090.04	5.64
5208.42	12, R	19 199.68		9021.69	4	11 084.40	

[9] Zeit. für Wiss. Phot., 7, p. 73; 1909.
[10] Ann. der Phys., 50, p. 727; 1916.
[11] Astrophysical Journal, 49, p. 54; 1919.

The wave lengths of the two triplets in the left-hand column are taken from Kayser's Handbuch.

TABLE 3.—Arc Spectrum of Chromium

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5564.58	3, n	D	6630.01	3	A	7990.51	1	A
5628.64	3	A	6642.99	1	E	8007.97	1, h	B
5642.34	2, p?	D	6661.09	5	A	8061.29	1	B
5648.12	2, p?	D	6663.93	1, p?	E	8084.98	1	A
5649.41	2, p?	B	6669.25	4	A	8163.21	3	B
5664.10	4	A	6677.20	2, p?	C	8166.64	1	D
5681.21	2	C	6680.18	2, p?	C	8235.90	2	B
5682.50	3	C	6715.36	3, h	A	8238.26	1	B
5683.60	1	B	6729.74	3, h	A	8287.38	1	B
5694.81	5	B	6734.16	2	A	8290.59	1, h	D
5698.33	5	B	6744.65	1	B	8348.27	2	B
5702.31	4	A	6746.65	1	C	8450.25	2	B
5712.75	4	A	6751.28	2	A	8455.22	2	C
5719.87	2	A	6757.77	2	A	8483.45	1, h	E
5729.23	1, p?	D	6762.42	2	A	8511.08	1	E
5738.54	1 p?	B	6772.37	2, n	A	8537.89	1	E
5746.44	1, p?	A	6828.81	2, n	E	8548.82	2	A
5753.68	2	A	6830.42	2, n	A	8555.55	1	D
5771.62	2, h	C	6881.62	9	A	8562.63	1, h	E
5781.09	9, n	B	6882.38	9	A	8583.07	1	E
5781.81	9	B	6883.03	9	A	8636.32	1	E
5783.12	9	A	6924.14	10	A	8643.02	1	D
5783.95	9	A	6925.20	9	A	8687.55	1	E
5785.01	8	A	6925.99	1	A	8707.48	1	E
5785.82	8	B	6978.51	10	A	8707.98	1	E
5787.06	2	B	6979.79	7	A	8718.78	1	E
5788.01	9	A	6980.81	2	A	8947.21	2	B
5791.00	10	A	6981.04	3	B	8976.88	3	A
5794.71	3, n	C	7170.63	2, p?	B	9009.95	6	B
5796.76	1, p?	E	7185.51	2	A	9017.10	5	B
5844.69	2, p?	E	7188.07	1	B	9021.69	4	B
5854.21	2, p?	E	7355.93	10	A	9035.88	3	B
5866.94	2, p?	E	7400.22	10	A	9140.37	1, h	C
5902.13	1, p?	E	7462.34	10	A	9141.13	1, h	B
6051.91	3, n	B	7722.88	2	C	9142.62	1, h	C
6135.75	2, p?	E	7724.63	1	E	9208.33	2	C
6190.64	2, p?	E	7726.00	1	B	9263.92	2, O?	C
6330.10	4	A	7762.99	1	B	9290.42	4	B
6362.83	4	A	7861.30	1	E	9294.11	2	C
6394.64	3, n	A	7885.01	1	E	9447.00	3	C
6537.95	2	B	7908.30	2	A	9571.70	0	C
6572.90	2, p?	A	7910.48	1	A	9574.22	2	C
6594.71	2	A	7917.84	1	A	9670.46	1	D
6597.55	2	A	7942.00	2	A	9734.51	1	C
6612.15	2	A	7989.37	1	A			

4. MANGANESE

In the arc spectrum of manganese 193 lines (Table 4) have been measured between the limits 5500 A and 9600 A. Wave lengths in the international code in the red region of the spectrum have been published by Kilby,[12] whose measurements extend to 6022 A, and by Fuchs,[13] whose measurements extend to 7070 A. In the infra-red region Randall and Barker [14] give three lines which are included in our list.

[12] Astrophysical Journal, **30**, p. 259; 1909.
[13] Zeit. für Wiss. Phot. **14** p. 245, 1915.
[14] Astrophysical Journal, **49**, p. 57; 1919.

Among the lines of Table 4, two new pairs have been found with constant frequency differences of the type found by Paulson.[15] They are as follows:

λ		ν	Δ ν
5505.88	3	18 162.40	35.85
5516.77	7	18 126.55	
7283.80	6	13 729.10	35.95
7302.92	6	13 693.15	

TABLE 4.—Arc Spectrum of Manganese

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5505.88	3	B	6349.75	3	B	7302.92	6	A
5516.77	7	B	6356.08	2	B	7305.13	1	E
5520.49	1	B	6370.81	2, h	B	7326.55	7	A
5537.70	7	C	6378.94	3	B	7342.85	1	E
5543.44	1	E	6382.18	3	B	7353.95	1	E
5552.02	5	B	6388.97	1	B	7376.87	1	E
5567.78	4	C	6391.24	2	B	7383.59	1	E
5573.10	3	B	6413.93	3	B	7387.31	1	E
5573.75	3	C	6440.95	5	B	7391.68	1	E
5602.02	2, h, n?	B	6443.48	3	B	7415.85	2	E
5718.16	3	B	6475.35	2	B	7425.57	1	E
5720.24	4	B	6483.02	1	B	7432.38	1	E
5723.81	2	B	6490.61	2	C	7447.90	1	E
5725.84	1	B	6491.71	7	A	7515.72	2	C
5738.27	3	B	6518.79	2	A	7552.20	1	C
5741.46	1	E	6519.38	3	A	7603.39	2	C
5748.54	1	B	6526.52	2, g coin?	B	7646.34	3, b, h	C
5780.15	3	B	6533.50	2	B	7651.91	3, b, h	D
5792.46	1	C	6534.08	2	A	7656.24	2, b, h	D
5805.90	1	B	6552.01	1	B	7668.00	2	D
5813.01	1	C	6558.01	1, Mn?	B	7670.46	2	D
5816.84	3	B	6569.30	1	C	7677.80	1, b, h	D
5822.55	1	C	6570.82	3	C	7680.20	5	A
5835.38	1	B	6598.31	2	C	7706.64	2	D
5848.98	3	B	6605.58	4	B	7710.21	5	B
5868.18	1, p?	B	6691.59	2	B	7712.42	5, h	B
5879.18	2, p?	B	6709.02	1	B	7721.55	1	B
5882.50	2, b, p?	A	6833.90	2	A	7727.22	1	D
5888.12	1, p?	E	6863.08	2	C	7733.23	4, h	A
6013.50	10	B	6867.18	2	C	7734.49	2	B
6016.65	10	B	6887.73	3	B	7737.13	1	B
6021.81	10	B	6931.27	3	B	7752.78	2	D
6041.76	2	B	6942.57	5	A	7755.07	3	D
6047.28	1, h	E	6989.85	4	A	7764.75	5	A
6057.11	2	B	7012.22	2, h	B	7790.91	2	D
6078.41	3, Mn?	B	7052.39	1	E	7805.99	2	B
6090.14	2	B	7069.86	4	A	7816.59	2	B
6095.68	1	C	7151.33	8	A	7821.25	2	B
6109.06	3	B	7158.14	2	C	7834.32	2, b	B
6114.33	2, Mn?	C	7171.21	1	E	7854.34	1	E
6176.06	1	E	7174.46	2	E	7916.31	1	E
6177.16	1	E	7184.29	5	A	7920.44	1	E
6177.52	1	E	7203.00	1	E	7928.45	1	E
6178.51	1	E	7209.58	2	E	7942.87	2	C
6223.78	1	E	7211.93	2, h	E	7948.06	1	C
6237.70	1, h	E	7247.83	5	B	8079.42	1	E
6265.67	2	C	7255.24	1, h, d?	E	8105.89	1	E
6268.48	1, h	E	7275.73	2	E	8110.47	1	E
6315.05	2	C	7283.80	6	A	8160.84	1	E
6344.11	3	B	7301.44	1	E	8212.43	2	B

[15] Astrophysical Journal, 40, p. 300; 1914.

TABLE 4—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
8227.04	1	E	8600.39	1	E	8734.64	1 Mn?	B
8280.73	1	E	8602.07	1	E	8737.29	2	B
8287.76	1	E	8654.60	2	B	8740.91	3	B
8373.97	1	E	8659.35	2	C	8767.94	1	E
8380.76	1	C	8664.66	1, b, h	E	8796.71	1	E
8395.82	1, b, h	E	8666.31	1, b, h	E	8798.76	1, h	E
8408.36	1	E	8670.85	2	B	8929.66	1	E
8409.86	1	C	8672.08	2	B	8933.03	1	E
8417.37	1	E	8674.01	2, h	B	9084.34	1	C
8421.31	1	E	8699.13	2	B			
						9114.08	1	C
8425.54	1	E	8701.04	2	B	9172.13	1	D
8431.14	1, b	D	8703.73	3	B	9243.21	1	C
8435.19	1	E	8710.14	1	E	9576.02	1	E
8521.54	1	E	8717.31	1	E			
8558.52	1	E	8731.76	1	E			

5. MOLYBDENUM

Table 5 contains 545 lines in the arc spectrum of molybdenum measured between the limits 5500 A and 9800 A. The spectrum of this element is characterized by a very large number of faint lines and a relatively small number of stronger lines. The measurements were rather difficult because of the strong background of continuous spectrum, probably due to the incandescent oxide that is formed, which is present on all the plates. It is hoped that the table is free from the lines of impurities, calcium and sodium being the only ones recognized thus far.

Our measurements are in fair agreement with those made by Weigand,[16] who measured the arc spectrum of molybdenum between the wave-length limits 4647 A and 7134 A.

Paulson [17] has given a number of pairs of lines with constant frequency differences. Additional groups found among the lines of Table 5 are:

λ		ν	Δν
5506.54	9	18 160.23	
5533.06	10	18 073.18	87.05
5570.57	7	17 951.49	121.69
5650.15	4	17 698.64	
5689.22	7	17 577.10	121.54
5722.78	5	17 474.02	
5751.42	6	17 387.01	87.01
5791.88	6	17 265.55	121.46
5858.28	7	17 069.86	
5888.32	6	16 982.77	87.09
8328.43	5	12 007.07	
8389.28	6	11 919.98	87.09
7242.54	7	13 807.31	
7485.73	7	13 358.75	448.56

[16] Zeit. für Wiss. Phot., **11**, p. 261; 1912.

[17] Paulson, Dissertation, Lund, 1914; also Astrophysical Journal, **40**, p. 302; 1914.

TABLE 5.—Arc Spectrum of Molybdenum

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5501.76	3	C	5741.74	2	B	5965.52	1	C
5503.60	2	E	5746.85	1	E	5968.47	1	C
5506.54	9	B	5747.61	1	C	5970.50	1	E
5511.51	2	E	5751.42	6	B	5974.25	2	B
5513.89	1	E	5765.33	1	E	5982.88	2	B
5517.54	1	E	5766.59	1	E	5988.12	2	C
5520.24	2	E	5769.78	1	B	5989.57	2	C
5520.76	2	E	5771.06	1	B	5990.01	1	E
5526.84	3	C	5774.47	2	C	5991.34	1	C
5529.32	1	E	5775.97	1	E	6000.88	1	E
5533.06	10	C	5778.13	1	B	6003.99	1	E
5537.85	1	E	5779.30	2	B	6011.29	1	C
5539.48	2	C	5780.07	1	C	6012.26	1	E
5541.73	1	E	5780.71	1	E	6013.09	1	E
5543.14	2	B	5783.33	2	A	6025.51	2	B
5544.57	2	C	5785.69	1	B	6027.26	1	B
5552.13	2, h	C	5791.88	6	B	6030.65	9	B
5556.56	3, d?	B	5795.74	2	B	6036.40	1	E
5562.56	1	E	5800.41	2	B	6039.72	1	C
5564.12	2	B	5801.45	1	B	6047.89	2	B
5566.76	1	E	5802.70	2	B	6050.96	1	C
5568.70	2	C	5803.99	1	B	6054.84	2	A
5570.57	7	B	5806.29	1	C	6058.01	1	A
5575.21	2	B	5806.69	1	B	6063.90	1	B
5580.19	1	E	5808.14	1	B	6075.56	1	C
5591.67	2	B	5809.13	1	E	6079.58	2	C
5594.86	1	C	5812.51	1	C	6081.25	2	B
5596.39	1	C	5813.93	2	C	6086.72	1	B
5608.69	2	B	5815.62	2	B	6096.20	1	C
5609.46	2, d	B	5820.68	1	B	6101.87	3	C
5611.00	3	B	5825.19	3	B	6107.23	1	E
5613.15	2	B	5827.02	1	E	6110.61	2, b, d?	B
5618.50	2	B	5835.63	1	B	6111.87	1	E
5619.56	2	B	5839.98	1	A	6119.00	1	E
5627.19	1	E	5841.76	1	E	6120.61	1	C
5632.48	4	B	5848.82	2	B	6123.69	2	B
5634.91	3	B	5849.76	3	B	6125.41	1	B
5650.15	4	B	5851.52	3	B	6128.19	2	B
5651.44	1	C	5854.36	1	E	6130.77	2	B
5652.07	2	C	5858.28	7	A	6138.63	1	E
5655.49	1	E	5861.41	2	B	6148.56	1, b, h	C
5662.56	1	E	5869.32	4	B	6158.43	2	C
5664.44	2	B	5871.54	1	C	6169.11	1	C
5667.34	2	B	5874.23	1	B	6170.79	1	B
5672.14	2	B	5876.55	2	A	6175.56	1	C
5673.60	2	B	5878.16	1	A	6189.01	2	B
5674.55	2	B	5881.50	1	A	6193.20	1	B
5677.93	2	B	5882.78	1	B	6197.66	2	C
5687.67	1	B	5884.33	2	B	6206.18	2	E
5689.22	7	A	5888.32	6	B	6208.31	1	E
5694.43	1	C	5891.65	2	C	6209.61	1	B
5696.02	1	B	5892.30	2	C	6213.28	1	C
5698.26	1	B	5893.41	3	B	6214.66	1	C
5699.33	2	A	5897.84	1	E	6217.93	2	B
5702.15	1	A	5898.78	2	B	6228.63	1, h	C
5705.74	3	A	5899.72	1	B	6244.80	1	B
5708.03	1	A	5901.46	3	B	6264.27	1	B
5711.82	2	B	5912.11	1	B	6265.87	2	B
5715.17	1	E	5914.30	1	B	6281.89	1	C
5716.07	1	E	5917.55	1	E	6286.63	1	B
5719.38	1	E	5923.81	1	C	6290.74	2	B
5720.27	1	E	5926.33	4	B	6301.76	2	B
5722.78	5	A	5928.81	7	B	6323.54	1	C
5728.77	2	B	5933.39	1	E	6339.90	1	B
5729.75	2	A	5937.89	2	B	6357.22	4	B
5734.07	2	B	5943.60	1	C	6358.58	1	E
5735.34	1	E	5949.14	1	B	6372.27	1	C
5736.55	1	E	5951.97	2	B	6383.70	1	E
5738.12	1	E	5957.68	1	E	6389.03	2	B
5739.62	1	B	5962.72	1, h	C	6391.03	2	C

TABLE 5—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
6401.08	2	B	6724.89	1	E	6999.10	2	A
6404.45	1, h	E	6728.02	2	A	6999.91	1	A
6406.56	1, b, h	B	6733.97	6	A	7001.62	3, Ni?	A
6409.10	3	B	6746.24	5	A	7011.78	1	B
6412.43	2, b	C	6753.99	3	A	7013.95	1	A
6412.92	1	E	6759.62	1	E	7016.46	2	A
6414.23	1	E	6761.58	1	E	7018.42	1	A
6418.95	1	D	6763.53	2	A	7019.61	1	A
6419.89	1	C	6764.94	1	A	7025.32	2	A
6424.37	5	B	6765.70	1	A	7032.30	1	B
6429.02	2	B	6767.94	1	C	7037.97	3	A
6439.80	2	E	6771.22	1	E	7045.29	2	B
6446.34	3	B	6773.36	1	E	7060.23	3	A
6453.30	2	B	6774.67	1	B	7063.34	2	A
6461.93	2	C	6778.63	2	A	7064.55	1	A
6463.57	1	B	6787.96	2	A	7073.55	1	A
6467.02	1	B	6789.01	2	A	7076.80	1	B
6471.22	3	B	6792.40	1	C	7079.24	1	B
6474.01	3	B	6794.56	1	C	7081.22	2	A
6476.34	1	B	6799.94	2	A	7083.12	1	B
6479.23	1	B	6802.62	2	A	7088.78	2, h	B
6485.97	3, b, h	B	6812.04	2	A	7098.18	1	B
6492.48	2	B	6822.03	1, h	A	7102.65	2	B
6493.16	2	B	6825.63	2	A	7105.59	2	A
6512.68	1	B	6829.05	3, h	A	7109.87	8	B
6519.83	3	A	6834.17	1	C	7122.65	3	A
6523.53	1	B	6838.89	4	A	7124.32	1	A
6527.62	1	B	6848.93	3	A	7127.31	1	B
6536.26	2	B	6852.80	1	E	7134.09	4	A
6537.66	2	B	6854.22	1, h	B	7135.73	1	A
6552.45	2	D	6859.40	1, h	B	7136.67	1	A
6553.47	1	D	6863.70	1	B	7146.24	1	A
6565.76	1, b, h	B	6865.46	1	B	7149.45	1	A
6569.74	2	B	6867.96	1	E	7154.15	1	A
6571.06	1	B	6874.66	1	E	7159.80	2	B
6572.31	1	B	6883.84	1	E	7171.85	1, h	B
6580.03	1	B	6886.34	4	A	7182.76	1	B
6590.87	2	C	6889.13	2, b, h	B	7186.54	1	E
6611.25	3	A	6892.37	3	A	7195.34	1	B
6619.16	8	A	6898.02	2	A	7198.28	1	E
6624.57	2	B	6899.03	2	A	7203.58	1	E
6634.01	1	B	6900.55	1, h	B	7216.98	1	A
6637.15	2	B	6904.73	2	B	7218.50	1	E
6649.43	1	B	6908.23	2	A	7219.27	1	E
6649.78	1	E	6910.98	1, h	B	7228.31	1, h	B
6650.40	6, h	B	6914.04	5	A	7240.48	1	A
6653.54	1	D	6917.61	1	B	7242.54	7	A
6657.01	1	B	6925.90	2	B	7244.56	1	A
6659.68	3	A	6929.03	1	B	7245.87	4	A
6672.22	1	D	6931.42	2	A	7249.89	1	E
6673.89	1	B	6934.12	2	A	7267.62	3	A
6675.42	1	C	6935.75	1	B	7277.21	1	B
6678.88	1, h	C	6937.12	1	B	7281.51	1	A
6679.59	1	C	6946.71	1	B	7295.03	1	A
6681.94	1	B	6947.46	2	B	7300.19	2	B
6683.26	1	B	6953.80	2	B	7311.11	1	B
6685.54	1	B	6957.08	1	B	7313.91	1, h	B
6687.88	2	A	6959.52	1	B	7315.36	1, h	C
6690.50	4	A	6960.66	2	B	7322.53	2, v, d	B
6691.04	2	B	6961.53	2	B	7325.37	1	C
6692.49	1	B	6978.75	3	A	7329.00	2, h	B
6696.66	2, b	B	6980.38	1	A	7331.51	2, h	A
6702.97	1	B	6984.71	1	A	7333.69	1	A
6717.40	1	B	6988.98	4	A	7338.92	1	A
6719.72	1	B	6991.71	2	A	7339.61	1	E

TABLE 5—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
7341.77	1	B	7679.50	2	B	8298.10	2	B
7348.48	2	B	7692.95	1, h	E	8328.43	5	B
7360.38	1	B	7707.68	1	B	8351.15	2	A
7361.63	2	B	7709.51	2	B	8389.28	6	B
7364.41	2, d?	C	7720.74	4	B	8420.79	1	B
7365.21	2	C	7723.62	2	B	8447.68	1	B
7383.15	1	B	7730.56	1	C	8450.23	2, h, n?	B
7391.36	5	B	7732.47	2	B	8483.30	2	B
7404.50	1	B	7745.86	1	B	8491.86	1	B
7411.83	1	C	7748.93	1	B	8498.47	1	B
7413.29	1	B	7752.29	1	B	8502.11	1	E
7414.27	1	B	7753.88	1	B	8507.58	1	B
7427.54	1	B	7774.53	1	E	8512.09	1	C
7431.38	1	B	7776.03	1	E	8539.87	1	E
7434.08	2	A	7784.46	1	E	8551.76	1	B
7447.30	2	B	7795.70	1	B	8553.71	1	B
7452.83	2	A	7801.12	1	E	8556.72	1, b	E
7456.65	1	A	7804.56	1	E	8594.56	2, v	C
7461.97	1	B	7809.67	1	E	8599.36	2, n?	B
7475.44	1	A	7811.23	1	B	8601.15	1	B
7485.73	7	A	7829.63	2	A	8614.27	2, n?	B
7496.49	1	E	7854.44	2	A	8617.02	1	E
7501.57	1	B	7861.96	1	E	8628.96	2	B
7504.45	2	B	7867.22	1	E	8642.00	1	B
7514.42	1	B	7869.36	1	B	8656.83	1, n?	C
7515.37	1	B	7877.00	1	E	8694.56	1	B
7521.00	1	A	7880.74	1	E	8695.53	2	B
7538.39	1	B	7887.75	2	A	8714.18	1	B
7548.71	1	C	7917.58	1	B	8731.72	1, h	E
7556.21	1	B	7923.16	2	B	8763.60	1, h	E
7568.78	1	E	7949.02	1	B	8765.70	1	E
7571.51	1	B	7968.84	1	B	8777.35	1	B
7572.61	2	A	7984.32	1	E	9067.46	1	B
7579.58	1	A	7986.58	2	A	9123.83	1	C
7581.32	1	B	7992.56	1	B	9177.21	1	C
7583.61	1	A	8008.86	1	E	9252.91	1	C
7591.67	1	B	8027.31	1	B	9348.01	2	B
7595.16	2	A	8045.57	1	E	9422.72	1	D
7601.82	2	A	8058.19	1	B			
7617.39	1	A	8071.05	1	E	9424.69	1	C
						9460.67	1, b	C
7618.78	1, h	E	8082.22	1	E	9721.50	1	E
7621.72	1	A	8086.35	1	E			
7624.98	1	B	8104.66	1, g?	C			
7631.46	1	B	8150.86	1	E			
7647.13	1	C	8153.45	1	B			
7649.52	1	B	8192.54	1	C			
7653.26	1	B	8203.76	1	B			
7656.74	4	B	8212.06	1	B			
7664.24	1	C	8245.06	3	B			
7676.63	1	E	8257.34	1	E			

6. TUNGSTEN

Between the limits 5500 A and 9200 A, 478 lines (Table 6) were measured in the arc spectrum of tungsten. With few exceptions the lines are faint; that is, of intensity 1 or 2. Tungsten, like molybdenum, gives out a strong continuous spectrum, which adds to the difficulty of measurement. Impurity lines present were due solely to molybdenum, several of its stronger lines appearing faintly among the tungsten lines.

The spectrum of tungsten to 6894 A has been photographed at Bonn by Fräulein Belke.[18] Our measurements agree very closely with hers. A few pairs of lines with constant frequency differences of the type found by Paulson[19] are listed below.

λ		ν	Δ ν
5486.04[20]	4	18228.09	94.97
5514.77	7	18133.12	
5978.91	2	16725.46	94.25
6012.79	4	16631.21	
6021.52	4	16607.10	94.28
6055.90	1	16512.82	
6820.25	4	14662.22	95.15
6864.80	2	14567.07	
7385.08	3	13540.81	94.91
7437.21	1	13445.90	

TABLE 6.—Arc Spectrum of Tungsten

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5500.62	2	C	5747.26	2	B	5934.49	1	B
5503.53	2	C	5749.22	2	B	5940.90	1	B
5508.65	1	E	5750.26	1	B	5947.56	4	B
5514.77	7	C	5753.41	1	B	5949.46	1	E
5521.16	1	C	5754.55	1	B	5953.97	1	B
5531.54	1	C	5756.16	2	B	5956.18	2	B
5533.26	1	C	5759.66	2	B	5960.83	2	B
5537.80	1	C	5772.00	1	B	5964.53	1	E
5539.60	1	C	5773.54	1	B	5965.88	4	B
5568.12	1	B	5789.83	1	C	5972.46	2	C
5576.28	1	C	5791.36	1	B	5976.66	2	B
5580.03	1	E	5793.02	2	B	5978.91	2	B
5593.65	1	E	5796.54	2	C	5983.84	2	B
5604.32	1	D	5799.53	1	C	5987.31	2, h, d?	C
5608.07	1	E	5803.10	1	E	5989.59	2, d?	C
5616.21	1	E	5804.86	4	C	5992.45	1	C
5617.33	2	C	5806.25	2	C	5998.24	1	E
5629.75	1	C	5822.60	2	B	6003.30	1	E
5631.30	1	E	5832.32	1	B	6008.99	1	B
5631.94	2	B	5833.62	2	B	6009.68	1	B
5635.50	1	E	5838.99	2	B	6012.79	4	A
5639.76	1	E	5845.28	2	C	6021.52	4	A
5642.12	2	C	5851.59	2	B	6028.32	2	B
5644.49	1	E	5854.45	1	C	6029.83	1	E
5648.42	4	C	5856.64	1	B	6035.52	1	E
5660.67	2	C	5864.64	2	B	6037.33	1	B
5664.40	2	C	5868.35	1, h	E	6041.62	2	B
5673.41	1	C	5869.91	1	B	6043.33	3	B
5674.45	2	C	5871.58	1	C	6046.66	1	C
5675.38	1	C	5874.24	1	C	6049.90	2	C
5676.85	2	C	5875.68	1	C	6053.18	1	E
5693.70	1	E	5880.21	2	B	6055.90	1	C
5697.86	2	C	5890.32	1	C	6057.45	1	E
5709.18	1	E	5891.59	2	B	6065.05	2	C
5715.35	1	E	5901.21	1	B	6066.82	1	E
5723.19	2	B	5902.66	2	B	6067.64	1	C
5728.60	1	C	5904.81	1, d?	E	6081.46	3	C
5735.11	4	B	5913.51	1	E	6082.86	1	E
5739.59	2	B	5928.61	2	B	6083.82	1	C
5741.20	1	C	5931.07	1	E	6092.29	1	C

[18] Zeit. für Wiss. Phot., 17, pp. 132 and 145; 1918.
[19] Paulson, Dissertation, Lund; 1914.
[20] Wave length given in Kayser's Handbuch

TABLE 6—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
6094.76	1	C	6435.39	2, h, d?	B	6733.06	2	A
6107.41	1	B	6438.03	1	E	6740.03	2	B
6111.67	2	B	6439.72	1	B	6745.51	1	B
6115.55	2	A	6445.13	2	B	6746.58	2	A
6119.35	1	A	6445.65	1	E	6754.56	1	B
6128.28	4	A	6448.16	3	C	6755.75	1	E
6129.60	1	E	6458.36	1	B	6764.43	2	A
6133.17	1	A	6461.73	1	E	6767.80	1	E
6140.97	1	E	6464.16	3	B	6770.05	1	E
6143.91	2	B	6474.78	1	A	6778.34	2	B
6147.18	1	B	6479.54	1	B	6799.35	2	B
6148.22	1	B	6484.09	2	B	6804.13	2	B
6151.68	2, h	B	6491.53	1	B	6805.31	3	A
6153.75	2	B	6494.85	1	C	6811.38	2	A
6154.88	2	B	6500.29	2, h	B	6814.93	3	A
6161.45	2	B	6508.01	2	A	6816.26	2	A
6169.11	2	A	6526.14	1	B	6820.25	4	A
6173.78	1	E	6532.40	3	A	6826.47	1	E
6179.66	1	E	6534.05	1	B	6828.43	2	B
6186.22	2	B	6538.16	4	A	6832.23	1	C
6187.54	1	A	6541.37	1	A	6838.61	1	B
6188.64	1	E	6552.84	2	A	6840.07	1	E
6193.23	1	B	6553.81	1	E	6844.88	1	B
6196.11	2, h	B	6554.24	2	A	6847.21	2	A
6203.54	4	B	6562.88	1	E	6853.73	2	A
6216.51	1	E	6563.16	3	A	6864.80	2	A
6219.50	1, h	E	6567.71	2	A	6874.93	2	A
6222.67	1	E	6569.75	1, h	A	6876.05	2	A
6224.21	1	E	6571.82	1, h	A	6877.60	2	A
6225.80	1	B	6573.96	3	A	6891.53	1, h, d?	B
6237.78	1	E	6582.90	2	A	6900.47	1	A
6245.74	1	B	6600.06	2	A	6908.31	3	A
6251.49	1	B	6607.17	2	A	6915.49	1	A
6253.62	1	E	6608.49	2	B	6917.21	1	A
6254.33	3	B	6609.06	2	B	6920.98	2	A
6258.93	2, h	B	6611.63	3	A	6934.29	4	A
6269.19	1	C	6620.60	1	B	6943.72	1	B
6279.51	1	B	6621.69	3	B	6955.57	2	A
6285.89	4	B	6622.39	1	E	6964.14	3	A
6288.90	1, h	E	6636.60	1, h	B	6971.67	2	A
6291.04	3	C	6639.15	1	E	6984.28	4	A
6292.02	4	B	6643.54	1, h	E	6989.31	1	A
6297.14	1	B	6643.84	1	E	6991.54	1	A
6298.57	1	B	6651.78	1, h	E	6993.15	2, d	A
6303.18	2	B	6653.96	1	E	6994.06	2	A
6308.47	1	B	6654.45	1, h	E	7002.73	1	A
6319.23	1	B	6656.51	1, h	E	7009.72	1	B
6331.38	1	B	6657.02	1	E	7016.01	1, d	A
6342.31	1	B	6659.14	1	B	7017.92	2	A
6355.84	2	B	6664.16	1, h	E	7020.23	1, h	B
6357.78	1	E	6664.83	2	B	7028.67	1	A
6359.15	1	B	6675.99	1	B	7044.18	1, h	E
6361.07	1	B	6677.19	2	B	7056.28	1, h	B
6364.77	1	B	6678.41	4	B	7058.79	1	B
6370.28	1	B	6682.65	1	B	7061.29	2, h	B
6371.43	2	A	6693.11	5	B	7071.05	1, h	C
6375.37	2	B	6701.79	1	E	7089.32	1	B
6382.51	1	B	6705.68	1	E	7098.23	2	B
6384.68	2	B	6708.18	1	E	7111.20	1	B
6386.47	2	B	6709.24	1	E	7116.90	1	E
6399.76	1	B	6710.58	1	E	7127.07	1	B
6402.07	2	A	6713.30	2	B	7140.51	3	A
6404.22	4	B	6718.57	1	B	7148.94	1	E
6416.02	2	B	6719.88	1	B	7162.64	2	A
6425.36	1	B	6725.19	2	A	7166.93	1	B

TABLE 6—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
7179.88	1	E	7630.24	1	B	8139.57	1, h	A
7184.71	1, h	E	7631.29	1	A	8143.14	2	A
7187.57	1	E	7643.40	1	B	8165.71	1	A
7191.33	1	A	7653.62	1	B	8210.20	2, Ba?	A
7198.62	1	A	7654.78	2	B	8222.52	1, h	A
7200.16	2	A	7664.86	3, K?	B	8311.60	1	B
7216.32	2	A	7672.32	1	B	8317.18	1	E
7218.16	1	C	7675.59	1	E	8321.98	1	A
7220.14	1	B	7679.15	1	B	8338.02	2	A
7226.02	2	B	7688.93	3	B	8348.77	1	A
7230.35	1	E	7689.96	1	B	8350.25	1	E
7231.68	1	E	7698.00	1	B	8358.66	2	A
7237.08	2	A	7699.42	1	B	8359.81	1	E
7245.23	1	B	7700.96	2	B	8368.23	1	E
7274.47	2, v	B	7736.16	1	E	8368.86	1	E
7278.21	2	A	7746.06	1	B	8382.88	2	A
7285.82	3	A	7754.90	1	E	8402.53	2	B
7291.83	1, h	B	7758.58	1	B	8409.50	1	E
7295.15	1	B	7761.13	2	B	8417.08	2	B
7296.57	3	A	7776.67	2	B	8431.91	2	C
7298.23	1	B	7784.11	3	B	8470.92	2	B
7347.88	1	D	7808.95	2	A	8475.15	3	B
7355.00	1	B	7823.76	1	B	8486.81	1	B
7361.70	1	B	7827.36	1	C	8495.06	2, h	B
7365.15	1	B	7839.45	1, h	C	8495.68	1	E
7368.39	1	B	7863.45	2	A	8497.37	1	E
7381.27	2	B	7867.01	2	A	8499.60	1	E
7384.04	1	B	7877.61	1	E	8506.95	2	B
7385.08	3	B	7878.56	1	E	8515.36	2	B
7389.00	1	B	7880.34	2	A	8516.37	2	B
7410.82	1	E	7883.17	1	C	8530.99	2	B
7429.03	1	C	7886.45	2	A	8577.75	1	E
7431.36	1	E	7905.25	2	B	8585.07	3	A
7433.47	1	E	7909.19	2	B	8594.38	3	A
7437.21	1	B	7914.28	1, h	B	8613.22	3	B
7439.45	1	B	7940.92	3	A	8614.49	2	B
7448.26	1	B	7955.43	1	B	8641.56	2	C
7451.37	2	B	7957.05	2	B	8710.76	1	C
7456.36	1	B	7967.16	1	E	8740.44	2	B
7459.23	1	B	7975.40	1	E	8744.64	2	E
7468.16	1	B	7985.59	1	E	8746.59	2	B
7471.55	1	B	7991.67	1	E	8754.83	1	E
7483.34	3	B	8017.17	4	B	8776.45	1	E
7504.07	2	A	8022.38	1	E	8777.45	1	E
7508.98	3	A	8039.04	1	E	8821.43	1	E
7520.63	1	A	8043.11	1	E	8823.39	1	C
7521.59	1	E	8054.87	1	B	8865.50	2	C
7525.44	1	E	8055.61	3	B	8871.65	1	C
7537.42	3	B	8058.14	1	E			
7550.46	2	A	8060.35	2	B	8883.66	1	C
						8915.83	1	C
7569.87	3	A	8063.33	1, h	E	8984.21	1, h	E
7582.85	2	A	8072.12	1, h, n?	B	9158.87	1, h	C
7604.74	1, h	E	8091.08	1	A			
7612.13	2	A	8123.78	3	A			
7614.07	3	A	8132.37	1, h	A			

7. URANIUM

The spectrum of uranium is very rich in lines, but none of them are very strong. Like tungsten and molybdenum, uranium emits a continuous spectrum, which renders the spectrograms difficult of measurement. Meissner[21] has published some wave lengths in

[21] Ann. der Phys., 50, p. 728; 1916.

the infra-red portion of the spectrum with which ours agree. Eder and Valenta[22] have measured the spectrum to 7130 A on Rowland's scale. A number of lines given by these observers and designated as "verbreitert," were not measured by us, perhaps because they were indistinguishable from the background of continuous spectrum.

A brief survey of our measurements has shown a number of pairs and groups of lines with constant frequency differences. They are:

λ		ν	Δ ν	λ		ν	Δ ν
5610.90	2	17 822.45	31.16	7761.82	2	12 883.58	30.92
5620.73	2	17 791.29		7780.49	1	12 852.66	
5634.37	2	17 748.21	31.16	6378.46	2	15 677.76	2.82
5644.28	1	17 717.05		6379.61	2	15 674.94	
5705.60	1	17 526.64	31.00	6620.50	2	15 104.60	2.81
5715.71	1	17 495.64		6621.73	2	15 101.79	
5800.80	1	17 239.00	31.09	7970.44	3	12 546.36	7.41
5811.28	1	17 207.91		7975.15	2	12 538.95	2.69
				7976.86	1	12 536.26	
5843.29	1	17 113.65	31.11	8381.92	2	11 930.44	7.58
5853.93	1	17 082.54		8387.25	2	11 922.86	2.66
5986.15	2	16 705.23	31.12	8389.12	2	11 920.20	
5997.32	2	16 674.11					
6378.46	2	15 677.76	31.03				
6391.11	1, h	15 646.73					

TABLE 7.—Arc Spectrum of Uranium

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5504.16	1	C	5614.86	1	E	5704.11	1	C
5510.44	1	B	5616.68	1, h	B	5705.60	1	C
5511.54	2	C	5620.73	2	B	5706.95	1, b	B
5513.40	1	B	5621.53	1	B	5709.56	1	E
5527.86	3	B	5624.52	1	E	5714.28	1	E
5531.22	1, v	C	5628.01	1, b, v	B	5715.20	1, g?	B
5538.59	1	B	5629.58	1, v	C	5715.71	1	B
5544.76	1	B	5634.37	2	C	5716.89	1	B
5548.04	1	B	5636.78	1	B	5718.99	1	E
5551.41	1	B	5637.95	1	B	5721.70	1	E
5552.66	1	C	5640.38	1	B	5722.31	1	C
5555.90	1	E	5644.28	1	E	5723.64	2	C
5557.91	1	B	5648.45	1	E	5733.34	1	C
5564.14	3	B	5653.73	1	C	5736.36	1	B
5570.72	1	C	5654.49	1	C	5737.27	1	B
5580.92	1	C	5658.28	1	B	5741.25	1	C
5581.41	2, v	D	5664.69	1, b	D	5742.80	1	E
5581.69	2	D	5669.44	1	B	5748.31	1, b 1	C
5587.18	1	E	5678.93	1	E	5750.54	1	C
5597.35	1	B	5680.37	1	B	5751.73	1	C
5602.93	1	B	5683.36	1	C	5757.35	1	C
5604.11	1	E	5685.26	1	C	5758.25	2	B
5607.09	1	E	5691.40	1	B	5760.35	1	E
5608.96	1, h	C	5695.04	1, b, d?	B	5761.87	1	E
5610.90	2	B	5702.95	1	C	5763.57	1	C

[22] Kaiser. Akad. der Wiss. Sitz., Wien, 119, IIa, p. 595; 1910.

TABLE 7—Continued.

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
5765.43	1	C	5988.39	1	E	6254.16	1	B
5767.57	1, b	C	5990.17	1	C	6261.41	1	C
5771.10	1	C	5997.32	2	C	6268.63	2, b, Cu?	C
5776.86	1	C	5997.98	1	B	6270.58	1	C
5777.80	1	C	5999.42	1	B	6279.59	1	C
5779.66	1	E	6000.25	1	B	6280.14	1	C
5780.59	2	B	6004.82	1	C	6291.97	2	C
5787.76	1	E	6005.73	1	C	6293.37	2	C
5788.60	1	C	6008.79	1	B	6298.55	2	B
5796.49	1	C	6010.99	1	E	6301.28	1	E
5798.57	2	C	6014.16	1	E	6304.61	1	B
5800.80	1	B	6016.70	1	C	6306.85	1	E
5802.13	1	C	6017.52	2	C	6321.28	1	E
5803.76	1	E	6019.17	1	C	6322.37	1	C
5805.33	1	C	6028.13	1	C	6330.74	1	E
5811.28	1	C	6039.65	1	C	6338.84	1	E
5812.30	1	E	6050.57	1	B	6346.19	1	E
5813.89	1	B	6051.74	2	B	6359.35	2	B
5814.54	1	C	6053.07	1	E	6369.86	1	C
5826.11	1	E	6056.95	2, d?	B	6372.46	2	B
5827.37	1	E	6059.73	1	C	6373.01	1	E
5828.05	1	E	6062.29	1	C	6374.60	1, b v	C
5830.80	1	C	6065.91	1	C	6375.91	1	C
5832.47	1	C	6067.22	1	C	6378.46	2	B
5834.06	1	E	6074.84	1	E	6379.61	2	B
5835.26	1	E	6077.28	2	B	6383.56	1	C
5836.10	2	C	6079.55	1	E	6386.78	1	E
5837.74	2	C	6080.40	1	B	6388.36	1	E
5839.11	1	E	6083.74	1	E	6389.80	2	B
5841.83	1	C	6084.91	1	E	6391.11	1, h	C
5843.29	1	C	6087.35	1	B	6392.75	2	B
5843.88	1	C	6089.16	1	B	6395.46	4	B
5845.25	2	C	6099.85	1	B	6397.19	2	B
5851.99	1	C	6101.76	1	B	6400.27	1	B
5853.93	1	C	6110.86	1	C	6404.40	1	E
5856.59	1	C	6112.07	1	B	6411.65	1	B
5859.21	1	E	6127.64	1	C	6424.89	1	B
5863.44	1	C	6129.76	2	C	6427.39	1	C
5870.93	1	B	6131.73	1	E	6428.83	1	B
5874.61	1	E	6132.65	2	B	6430.95	1	C
5886.98	1	C	6138.57	1	B	6449.20	4	B
5892.61	1	C	6140.37	1	B	6464.99	3	B
5893.75	1	C	6141.80	1	E	6470.58	1	B
5898.80	1	C	6152.26	1	B	6477.90	1	C
5902.54	1	C	6153.72	1	C	6479.91	1	C
5915.38	4	C	6157.59	1	E	6481.74	1	B
5925.39	1	C	6164.57	2	B	6487.05	1	E
5929.35	1	C	6165.68	1	E	6488.34	1	B
5930.33	1	E	6169.04	1	E	6495.35	1	C
5932.54	1	E	6171.91	2	B	6503.59	2	B
5933.85	1	C	6172.86	1	B	6506.32	1	B
5935.38	1, b, h	C	6174.42	1	C	6510.85	1	B
5948.53	1	B	6175.44	2	C	6511.21	1, b	C
5949.85	1	B	6181.36	1	E	6515.49	1	E
5952.06	1	B	6196.46	1	E	6517.73	1	E
5955.03	1	E	6198.40	1	E	6518.93	2	B
5956.89	1	C	6202.03	1	E	6520.95	1	C
5963.91	1	E	6203.30	1	E	6526.05	1	B
5971.56	2	B	6215.37	2	B	6527.11	1	B
5972.84	1, b	B	6222.12	1	C	6534.66	1	E
5974.79	1, b, v	C	6232.48	1, b	B	6535.41	1	B
5976.34	3	B	6234.31	1	B	6536.58	1	E
5982.72	1	E	6246.52	1	B	6537.54	1	E
5984.65	1	E	6248.07	1	E	6542.96	2	B
5986.15	2	B	6251.76	1	B	6544.01	1	E

TABLE 7—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
6545.81	1	C	6700.23	1	E	6876.77	2	B
6547.29	1	E	6701.63	1	B	6885.55	1	B
6549.88	1	B	6703.17	1	E	6887.62	1	B
6552.84	1	B	6704.59	1	E	6889.73	1, b, Cu?	C
6555.01	2	B	6710.57	1	C	6894.80	1	C
6556.00	1	B	6714.20	1	E	6897.00	1	E
6557.57	1	B	6717.47	1	B	6898.76	1	B
6569.40	1	E	6719.90	1	E	6900.20	1	B
6572.76	1	E	6720.78	1	B	6901.37	1	C
6575.18	1	E	6724.02	1	E	6902.54	1	B
6579.72	1	E	6726.86	1	B	6903.84	1	C
6582.74	1	B	6727.99	1	B	6913.81	1	C
6585.22	1, b	B	6734.83	1, b	E	6915.26	2	B
6587.80	1	B	6736.79	2	B	6917.02	2	B
6590.05	2	B	6738.11	1	E	6917.99	1	B
6595.52	1, b	E	6739.69	1	B	6922.58	1	B
6598.33	1	E	6748.30	1	B	6925.89	1	B
6601.45	2	B	6749.52	1	E	6927.66	1	E
6602.70	1	E	6751.64	1	E	6929.52	1	C
6603.39	1	E	6752.39	1	E	6933.46	1	E
6604.05	2	B	6754.92	1	B	6939.37	1	B
6607.36	1	E	6761.99	1	E	6942.46	1	B
6609.78	1	E	6767.37	1	E	6946.26	1, b	C
6620.50	2	B	6768.72	1	B	6947.08	1	E
6621.73	2	B	6769.33	1	B	6948.56	1	B
6622.85	1	B	6770.89	1, b	B	6949.65	1, b	C
6625.31	1	B	6776.85	1	B	6955.93	1	C
6629.16	1	C	6780.58	1	B	6957.89	1, b	B
6630.15	1	E	6782.74	2	B	6964.07	1	E
6631.04	1	E	6790.24	2, b	B	6965.84	1	C
6632.04	1	E	6792.31	1	E	6979.19	1	E
6633.43	1	E	6793.79	1	E	6984.44	1	C
6634.60	1	E	6794.80	1	E	6987.76	1	C
6637.40	1	E	6796.42	1	C	6989.98	1	E
6638.82	1	E	6799.50	1, b	C	6992.40	1	E
6640.49	1	E	6801.19	1	E	7006.14	1	E
6641.27	1	E	6802.63	1	E	7011.29	1	E
6641.74	1	E	6804.83	1	E	7014.14	1	E
6645.30	1	B	6807.30	1	E	7015.69	1	B
6646.02	1	E	6808.80	1	C	7017.08	1	E
6647.77	1	C	6810.15	1	E	7018.41	1	E
6653.40	1	E	6812.93	1	E	7020.70	2	B
6656.82	2	B	6813.87	1	E	7023.59	1	E
6657.68	1	E	6815.97	1	C	7026.15	1	C
6659.69	1	E	6818.26	2	B	7030.66	1	B
6661.31	1	E	6820.74	2	B	7033.83	2	B
6666.81	1	E	6824.47	1, v	B	7040.91	1	E
6668.35	1	E	6826.90	5	B	7045.22	1	C
6670.30	1	E	6829.27	1	C	7046.86	1	C
6671.27	1	E	6830.87	1	B	7048.97	1	E
6674.39	1	E	6832.71	1	B	7052.01	1	E
6675.80	1	E	6836.04	1	B	7053.96	1	E
6676.90	1	B	6839.92	1	C	7063.41	1	E
6677.70	1	E	6840.73	1	E	7073.59	1	C
6679.12	1	E	6846.22	2, n?	B	7074.78	4	B
6681.15	1	C	6848.76	1	E	7076.48	1	E
6683.43	2	B	6849.71	1	E	7078.75	1	E
6685.06	1	E	6851.93	1	E	7082.05	2	C
6687.63	1	C	6854.17	1	B	7091.42	1	E
6689.83	1	E	6859.86	1, b	B	7095.72	1	E
6691.16	1	B	6862.94	1	E	7101.61	3	B
6692.12	1	B	6864.56	1	B	7103.21	1	C
6694.28	1	E	6869.07	1	C	7105.18	1	C
6695.50	1	E	6872.35	1	E	7109.08	1	C
6699.22	1	E	6873.54	2	B	7116.06	1	D

TABLE 7—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
7119.46	1	E	7438.20	2	B	7669.69	2	C
7121.83	1	E	7443.07	2	B	7689.91	1	E
7126.19	2	C	7443.90	1	B	7691.89	1	C
7128.88	4	B	7447.85	1	B	7693.59	1	E
7130.06	1	B	7452.48	1	C	7696.88	1	B
7135.98	1	E	7453.93	2	B	7707.59	1	E
7137.95	1	E	7457.76	1	C	7718.87	1	E
7139.92	1	E	7467.06	1	C	7744.30	1	E
7141.18	1	E	7470.87	1	E	7747.09	1	C
7142.24	1	E	7476.08	1	E	7748.14	1	B
7144.06	1	E	7477.40	1	E	7754.16	1	B
7147.89	2	B	7480.49	1	C	7759.85	1	B
7152.08	1	E	7483.48	1	D	7761.82	2	B
7155.76	1	E	7484.88	1	D	7763.77	1	E
7164.93	2	B	7489.17	1	C	7766.57	1	E
7168.02	1	E	7494.21	1, b	B	7768.93	1	E
7170.68	1	E	7497.31	1	E	7776.94	1, b	C
7172.16	1	C	7499.50	1	E	7780.49	1	B
7175.92	1	E	7502.24	1	C	7782.38	1	D
7179.27	2, b	C	7504.95	1	C	7784.11	5	B
7183.46	2	D	7506.94	1, b	B	7791.24	1	E
7187.51	1	E	7510.04	1	B	7802.32	1	C
7189.35	1	E	7512.58	1	E	7808.36	1	C
7193.10	1	D	7514.37	1	E	7813.42	1	E
7194.64	1	C	7517.37	1	B	7816.27	1	B
7196.57	1	C	7528.68	2	B	7821.82	1	C
7205.39	1	C	7531.68	1	E	7823.79	1	C
7207.46	1	E	7533.91	5	B	7832.02	1	C
7209.24	1	C	7550.15	2	B	7835.57	1	C
7210.29	1	C	7552.13	1	E	7837.66	1	B
7212.08	1	C	7558.31	1	E	7844.75	1	B
7218.01	2	C	7560.69	1	E	7868.78	2	B
7228.08	1, b	C	7562.44	1	E	7875.34	2	B
7230.86	1	E	7566.02	2	B	7881.91	4	B
7251.94	1	E	7570.72	1	E	7895.92	1	C
7254.46	2	B	7572.37	1, b	B	7900.40	1	B
7256.57	1	C	7573.14	1	C	7904.22	1	B
7258.99	1, b	C	7575.80	1	B	7907.91	1	B
7273.71	1	C	7580.79	1	B	7918.76	1	B
7279.79	1	E	7582.21	1	E	7922.04	1	C
7282.37	1	E	7587.68	1	B	7959.83	1	C
7293.97	1	E	7590.45	1, b	B	7963.95	1	B
7299.42	1	E	7595.06	1	B	7967.09	1	E
7312.45	1	E	7597.46	1, b	D	7970.44	3	B
7314.46	1	E	7600.27	1	C	7975.15	2, b, h	B
7315.87	1	E	7605.90	1	C	7976.86	1	B
7331.86	2, b, v	C	7609.15	2	B	7978.62	1	C
7333.56	1	C	7610.77	1	E	7989.13	1	C
7335.80	1	E	7615.72	1	E	7991.32	1	D
7341.66	2, h	C	7619.34	3	B	7995.44	1	D
7361.07	1	E	7621.86	1	B	7998.52	1	B
7368.65	1	D	7626.15	1	E	8002.91	1, h	D
7370.21	1	D	7627.96	1	D	8019.27	1	E
7372.09	2	C	7629.34	1	D	8034.69	1	B
7372.68	1	E	7630.44	1	E	8035.99	1	E
7375.40	1	D	7631.72	3	B	8055.56	1	C
7377.29	1	C	7632.70	1	E	8060.34	1	E
7379.63	2	C	7634.78	2	B	8065.68	1, b, h	B
7390.89	1	E	7639.56	2	B	8067.93	1	E
7392.11	1	C	7641.24	1	E	8074.03	1	C
7396.97	2	B	7643.67	1	E	8097.52	1	E
7416.36	1	C	7648.66	1	E	8174.29	2	B
7419.57	1	E	7653.55	1	C	8175.77	1	E
7425.49	3	B	7658.76	1	E	8188.18	1	B
7432.21	1	C	7668.59	2, h	B	8262.04	2	B

TABLE 7—Continued

λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error	λ I. A.	Notes	Probable error
8318.36	1	B	8557.36	1	C	9023.38	1, h	B
8327.79	1	E	8566.92	1	E	9093.61	1	B
8329.83	1	E	8567.72	1	E	9136.80	0	E
8337.49	1	B	8570.60	2	C	9139.21	1	E
8346.74	1	C	8574.55	1	C			
						9140.97	1	E
8357.07	1	E	8607.92	3	B	9143.20	1	E
8381.92	2	B	8612.82	1	E	9276.24	1	E
8387.25	2	C	8618.77	1	E	9530.38	1, h	E
8389.12	2	C	8637.48	1	E			
8390.95	1	E	8641.09	1	E			
8396.82	1	E	8652.74	1	E			
8399.26	1	E	8659.50	1	E			
8426.70	1	E	8691.28	2	B			
8441.25	1	B	8710.73	2, h	C			
8445.35	2	B	8728.65	1	E			
8450.03	2	B	8753.64	1	C			
8496.09	2	C	8757.83	2	D			
8504.70	2	C	8860.62	1	E			
8531.10	1	E	8951.92	1	C			
8540.13	2	C	9020.89	1, h	B			

TABLE 8.—Faint Lines Common to the Spectra of Two or More Elements

λ I. A.	i	Notes	λ I. A.	i	Notes
5536.49	1	Co, Mn	7135.62	2	Mn, V, Ti
5554.97	1, O?	Mn, Cu	7139.71	2	Mn, V
5752.85	1	Co, Ti, V	7221.22	2	Fe, Mn
5756.81	1	Fe, Ti	7443.49	2	Co, Mn
5995.77	1	Co, Ti	7483.43	2	Fe, Mn, U
6062.90	1, Nh?	Fe, Mn, Si	7552.22	2	Ni, Mn, U
6078.44	3	Fe, Mn	7624.79	2	Ni, V
6114.30	1	Co, Mn	7735.95	1	Ni, Mn
6374.51	1	Co, V	8028.32	2	Fe, Ni, Cr, Mn
6529.08	1	Fe, Cr	8032.45	1	Co, Mn
6558.03	2	Mn, V	8179.05	1	Fe, Mn
6777.82	1	Mn, Cr	8481.76	1	Mn, V
6789.25	3	Co, Cr	8514.02	2, Ba?	Fe, Mn
6906.36	1	Co, Mn	8569.75	2	Co, Ti
6933.62	2, Yt?	Fe, Mn	8734.66	1	Mn, Ti
			8945.15	1	Fe, Ti
			9012.04	1	Fe, Ni, Ti

8. FAINT LINES COMMON TO SEVERAL SPECTRA

Table 8 contains about 30 faint lines which appear with equal intensity in the spectra of two or more elements. Undoubtedly these lines owe their origin to some common impurities which have not as yet been identified. In a previous paper [23] attention has been called to the presence of two groups of lines belonging to oxygen, which appear in the arc spectra of metals. These lines have been measured repeatedly during the work described in this paper, and, in addition, other lines agreeing in wave length with lines in the series spectrum of oxygen have been

[23] B. S. Bulletin, 14, p. 644; 1918; see also Paschen and Runge, Phys. Zeit., 14, p. 1267; 1913.

observed. Thus, the line 5554.97 has been measured in the spectra of manganese and copper, 6456.06 in that of titanium, and 9263.92 in the spectrum of chromium. This last line was not given by Randall and Barker [24] in the list of infra-red chromium lines observed by them with the bolometer.

IV. SUMMARY

The concave-grating spectrograph of the Bureau of Standards was used in photographing the yellow, red, and infra-red arc spectra of titanium, vanadium, chromium, manganese, molybdenum, tungsten, and uranium. The photographs were made on plates sensitized to the red and infra-red rays with pinacyanol and dicyanin. American-made dyes were used for many of the plates and were as effective in their sensitizing power as their predecessors. More than 2600 wave lengths were derived from the measurement of the plates, many of them being the wave lengths of heads of bands which are prominent in the spectra of titanium, vanadium, and chromium. Impurity lines have been eliminated from the tables, so far as known, those not identified being brought together in a separate table. Lines whose wave lengths agree with those in the series spectrum of oxygen have been observed in the spectra tabulated above. Frequency differences which are suspected of being constant have been found in each of the spectra here presented.

WASHINGTON, November 8, 1919.

[24] Astrophysical Journal, 49, p. 54; 1919.